Update on DVCS

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EIC Task Force meeting

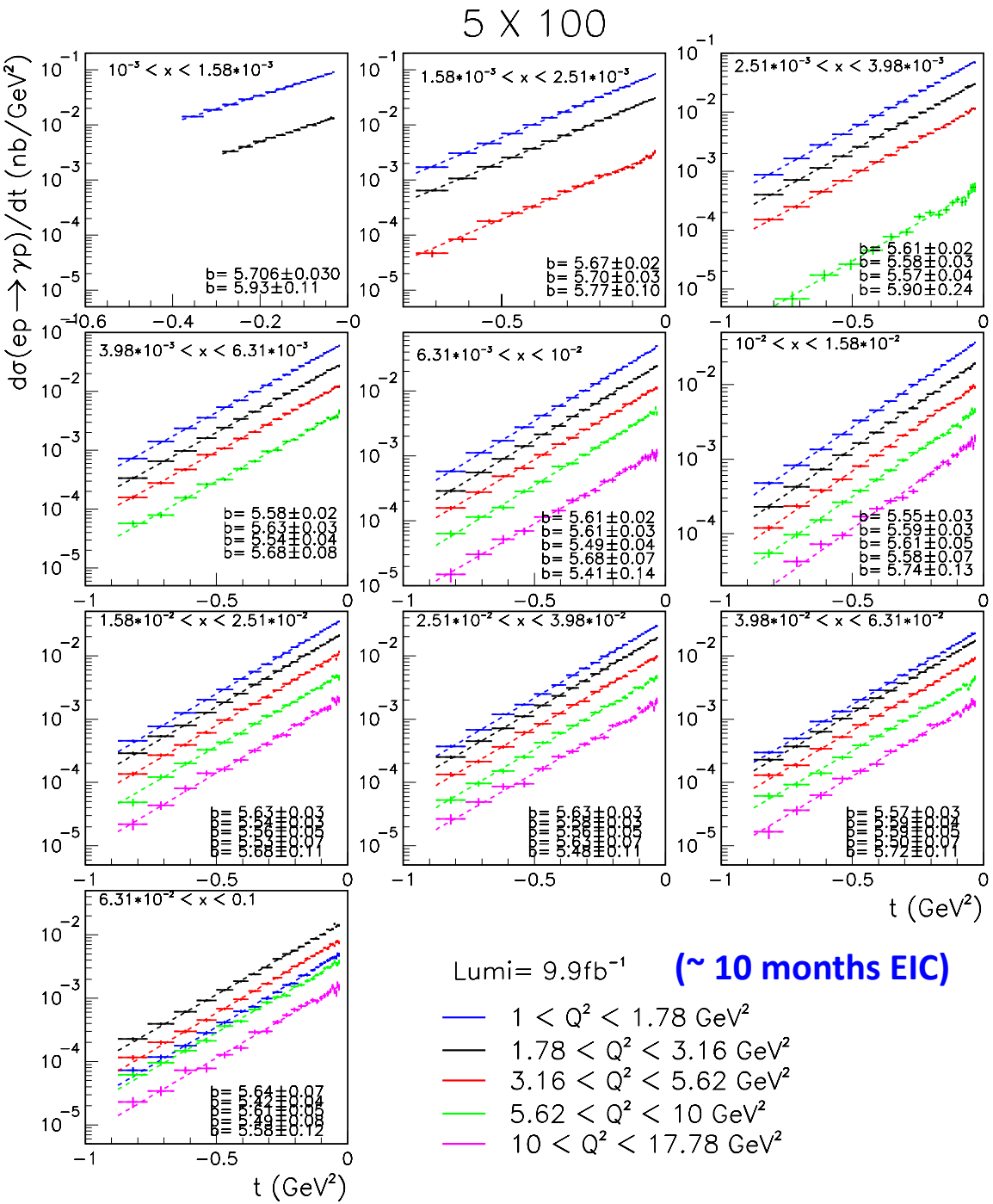
BNL – Feb. 15th, 2012

Summary from November

- **The spin asymmetry code problem has been fixed**
- **We have a way to show the great potential of an eRHIC to transverse target-spin asymmetries**
- **The differential cross-sections now are simulated using a smeared variable and with a 3*reso binning**
- **Systematics can reasonably considered in the order of 5%**
- **Mock data have been used for global fits with the existing HERA data to extrapolate GPDs, the impact of an eRHIC on the present knowledge can be huge even after a moth of data taking at the 20x250 energy configuration.**

Outlook:

- **Scan also the 5x100 GeV energy configuration**



|t|-differential x-sec

$$\frac{d\sigma}{d|t|} = \frac{\#evt}{\Delta_{bin} \bullet \mathcal{L}} \qquad \sim e^{-bt}$$

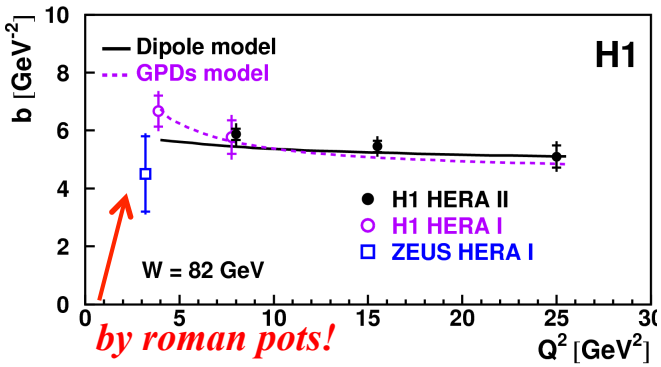
b=5.6

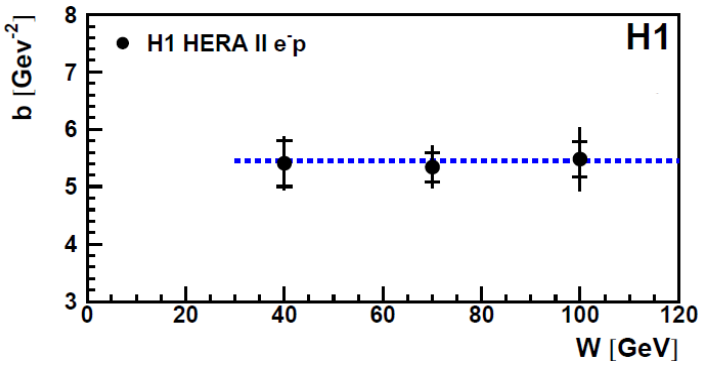
Specifications:

- **y>0.01 (EIC detector acceptance)**
- **It uses smeared t values (5% momentum resol.)**
- **The binning is now not uniform (3*reso)**
- **The b slope 5.0 -> 5.6 compatible with H1 data, to facilitate Dieter's global fitting**

Mock data for Aut coming in a few days

Scanning the phase space…





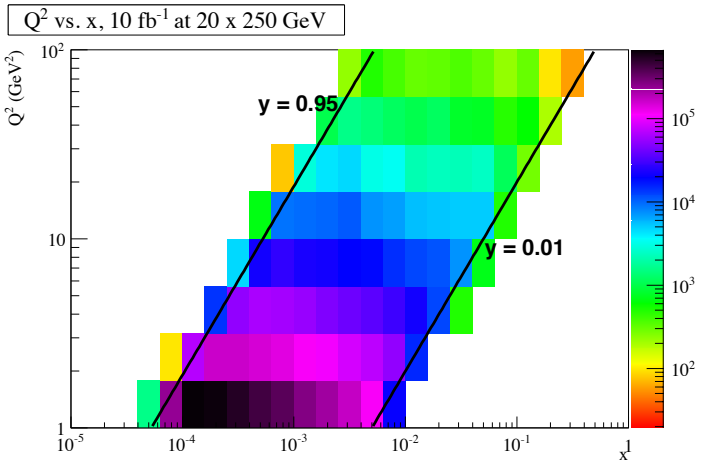
EIC lumi:
11.6 fb^{-1}/month @ 20x250

- **EIC will provide sufficient luminosity to bin in multi-dimensions**
- **wide x and Q^2 range needed to extract GPDs**

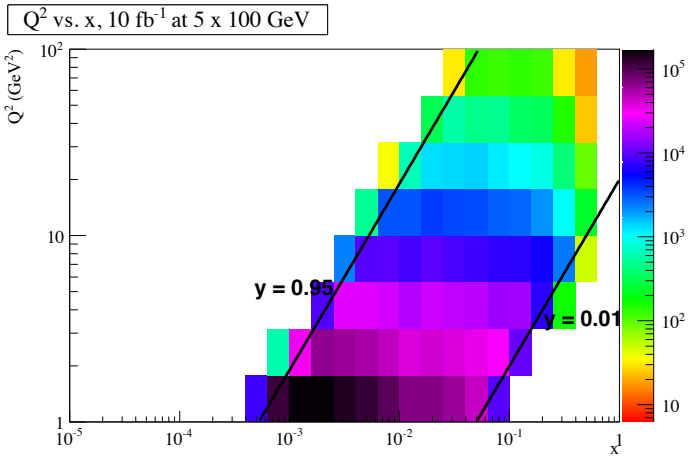
Logarithmic bins: $1 < Q^2 < 100\ GeV^2$

$10^{-4} < x < 0.1$

20 X 250

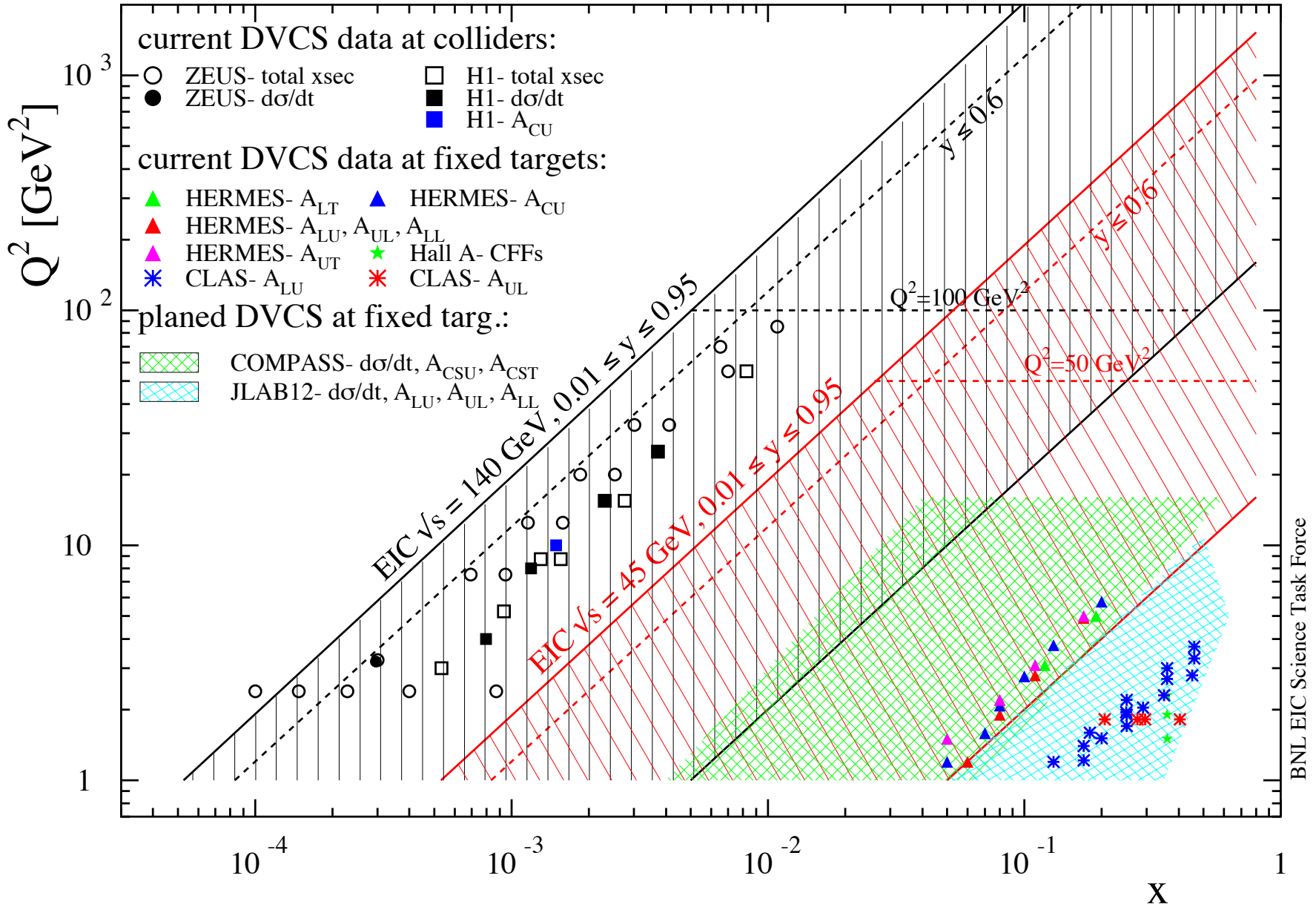


5 X 100

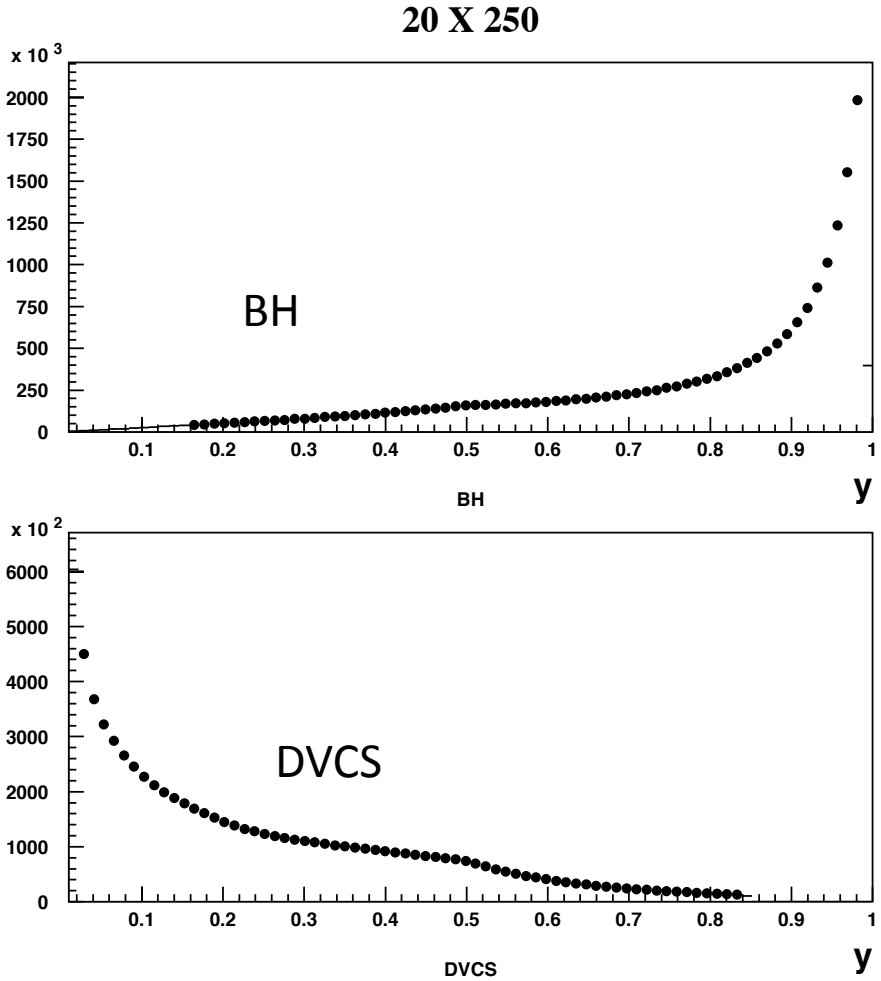


… we can do a fine binning in Q2 and W

EIC - DVCS phase-space



Fraction of Bethe-Heitler



BH events generated

- $0 < |t| < 1.0\ GeV^2$
- $10^{-4} < x < 0.1$
- $0.01 < y < 0.99$

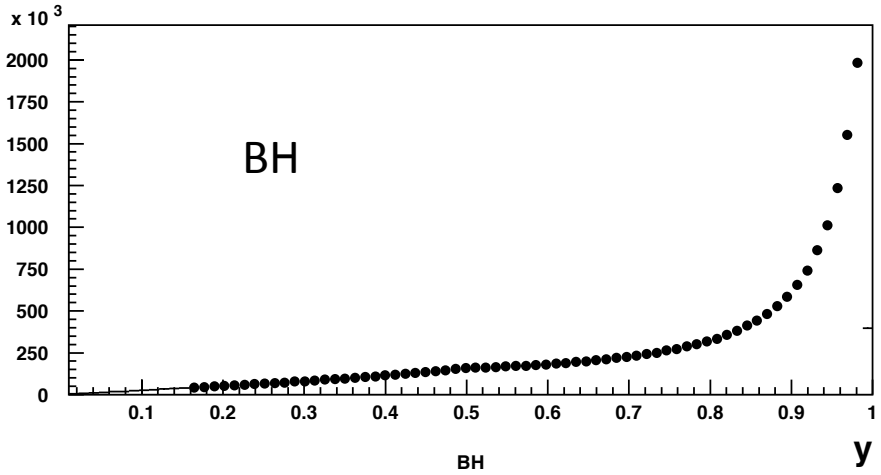
Same as DVCS

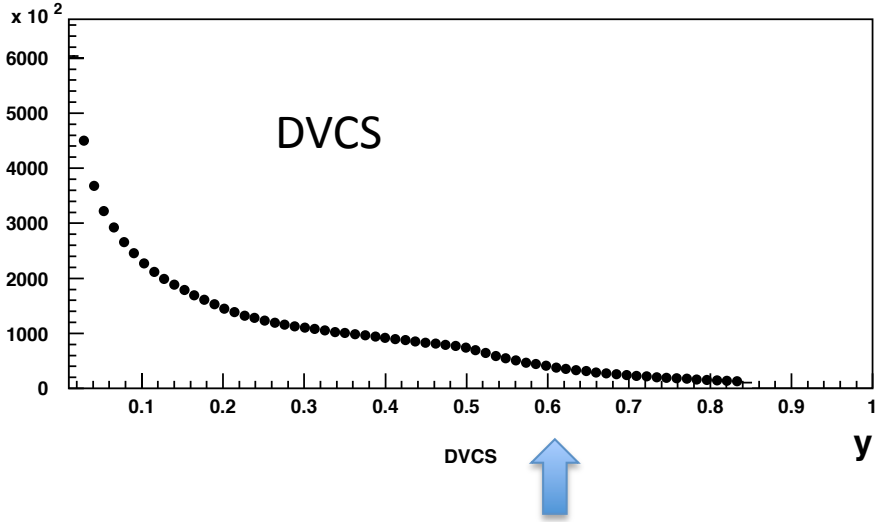
$$frac(BH) = \frac{BH_{evt}}{BH_{evt} + DVCS_{evt}}$$

- Proton dissociation not included for both DVCS and BH (but mostly process independent…)
- BH dominates at large y
- Part of BH will be removed by DVCS selection criteria

BH is “precisely” known but to certain level!
Uncertainty on proton form factor → **uncertainty on BH xsec ~ 4%**

20 X 250





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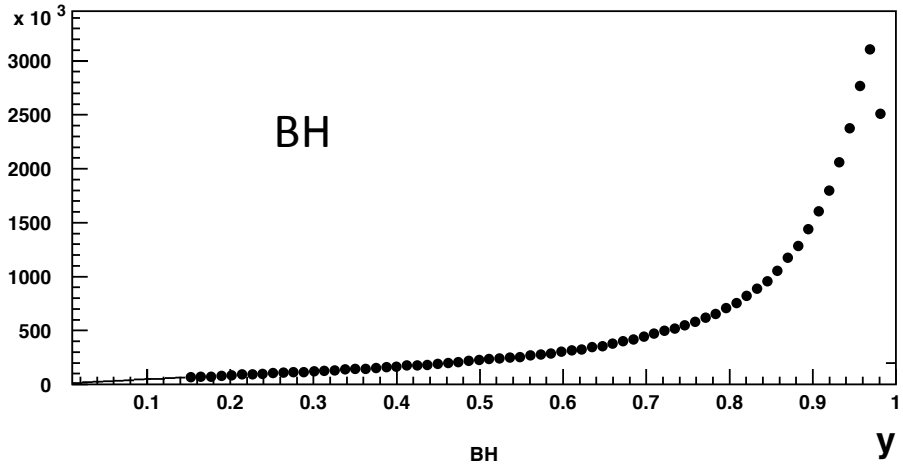
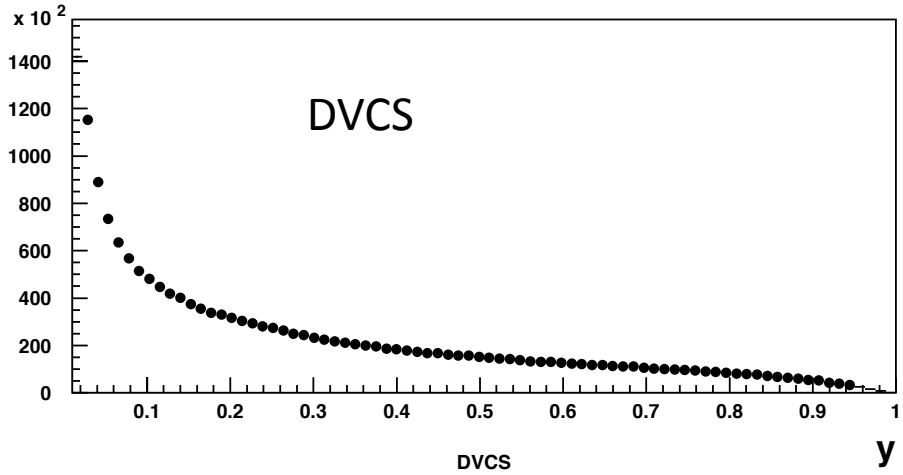
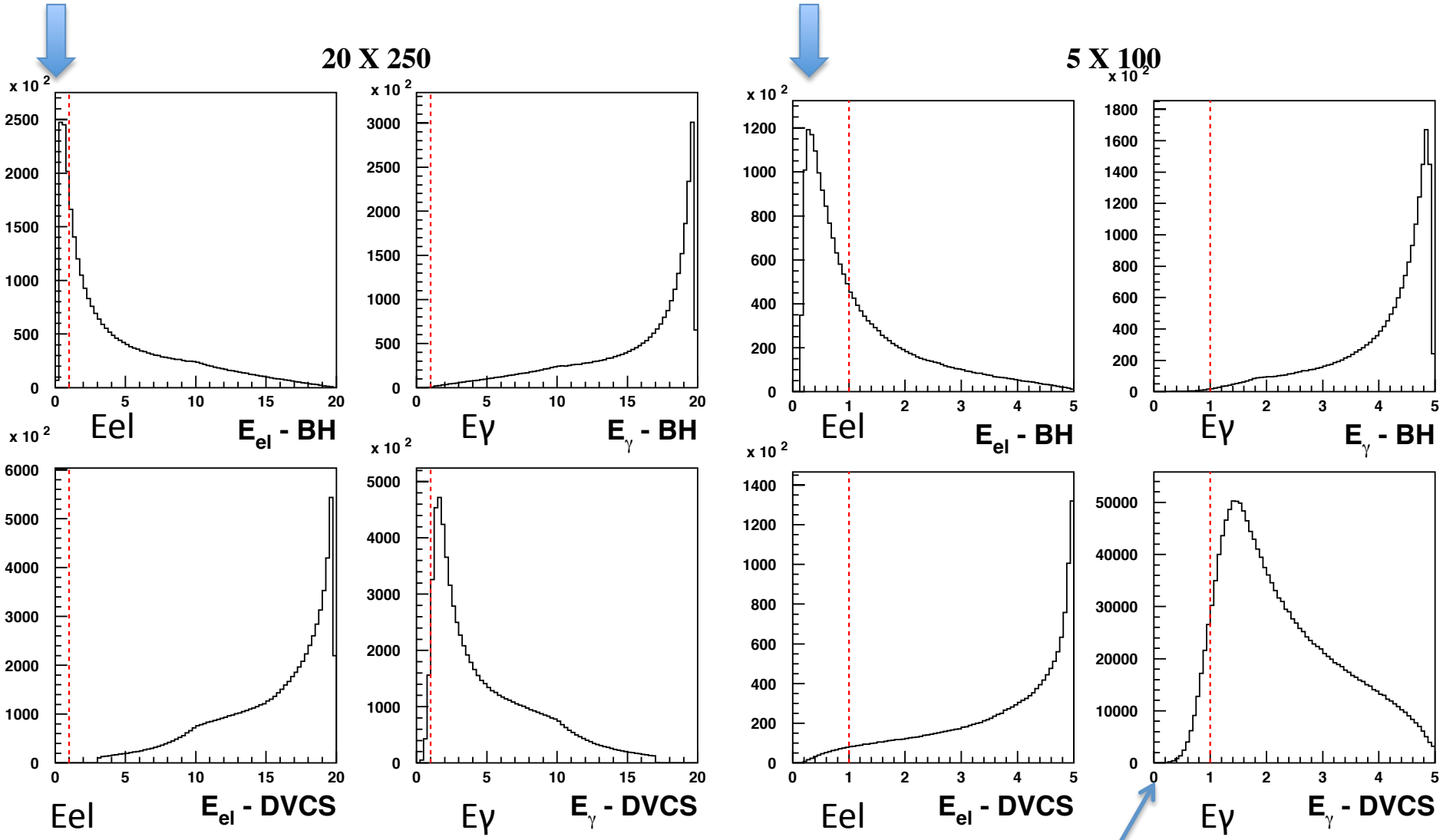




- BH dominates at large y.
- DVCS dopes with y

But…

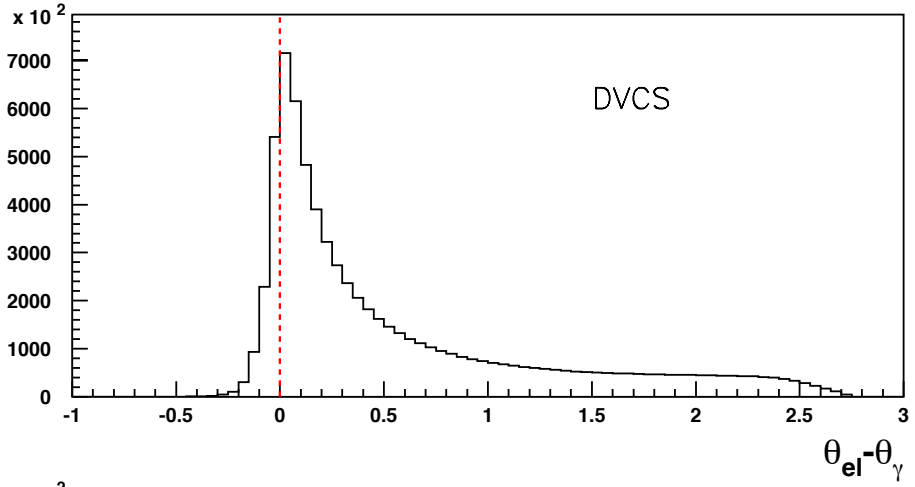


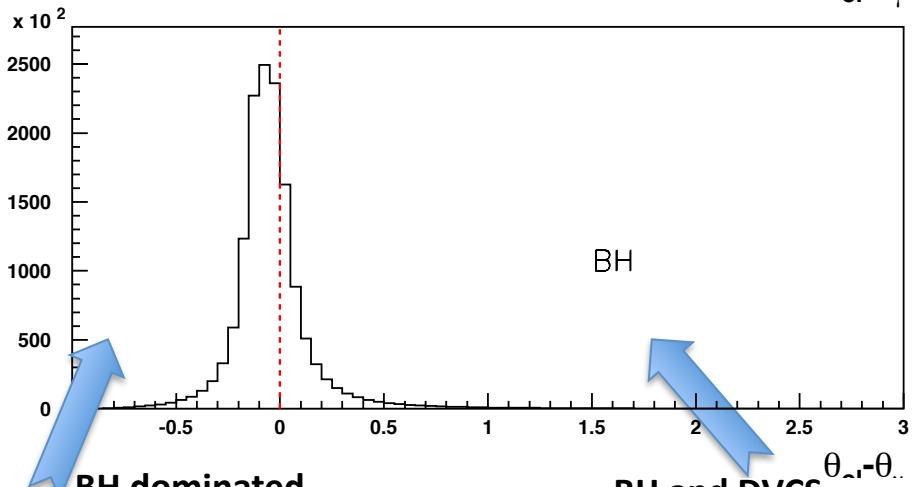
1. **BH photon has very low energy (often below 1 GeB)**
2. **Photon for BH (ISR) goes often forward (trough the beam pipe**

Important!
Em Cal must discriminate clusters above noise down to 1 GeV

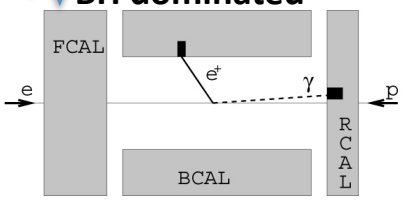
BH rejection

20 X 250

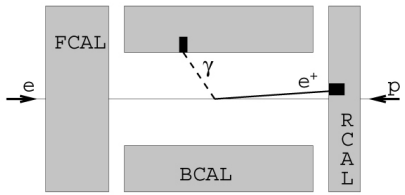




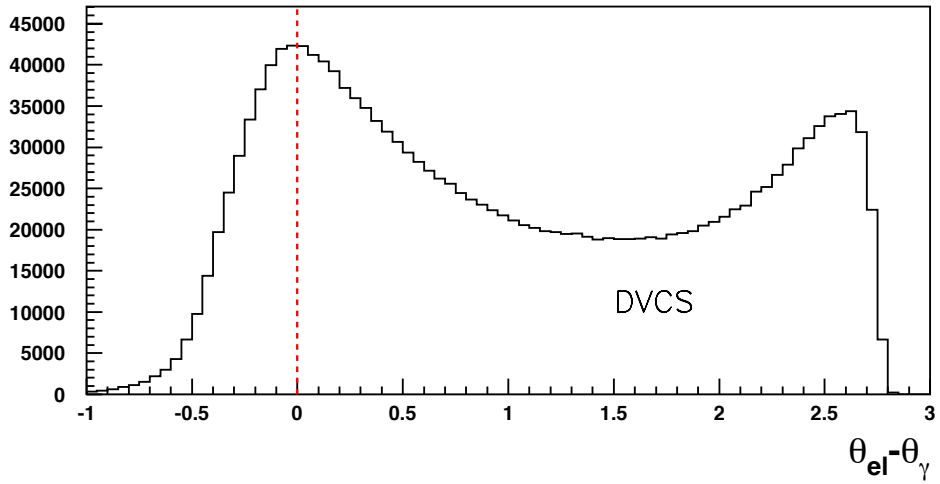
BH dominated

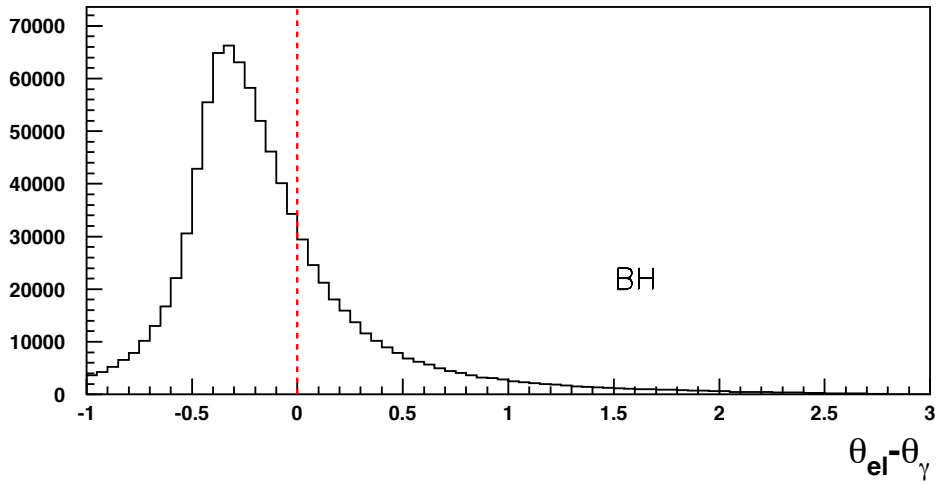


BH and DVCS



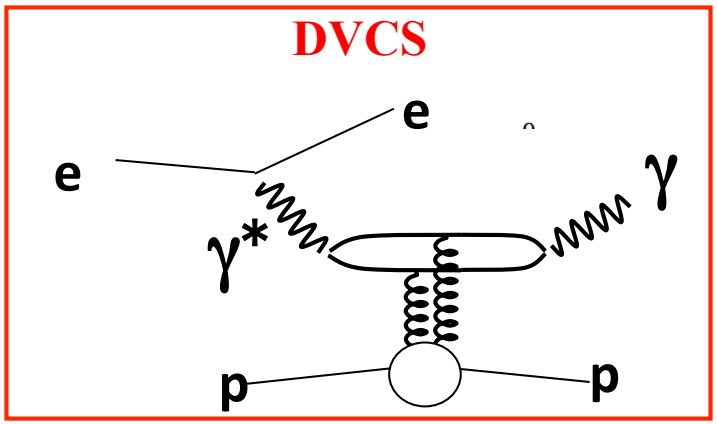
5 X 100

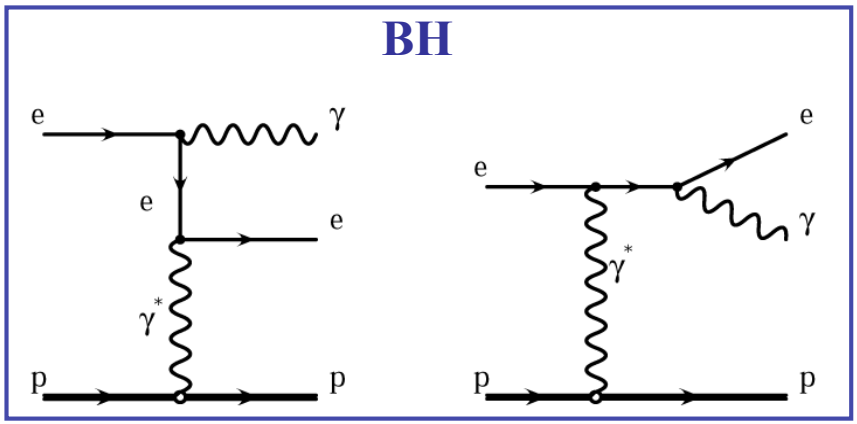


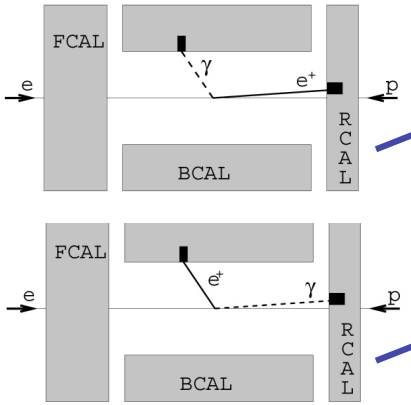


In DVCS most of the photon are less “rear”
Than the electrons

BH extraction – the HERA Strategy







γ sample: no tracks matching to the second candidate

(DVCS+BH)

e sample: a track match to the second candidate

(BH+ dilepton + J/ψ)

Wrong-sign sample: a negative track match to the second candidate

(dilepton + J/ψ)

The PHI angle reconstruction

$$|A|^2 = |A_{DVCS}|^2 + |A_{BH}|^2 + |A_I|^2$$

DVCS and BH: identical final state → they Interfere

Interference term: $A_I \propto Re(A_{DVCS}) + Im(A_{DVCS})$ **$|A_{BH}|$ is well known**

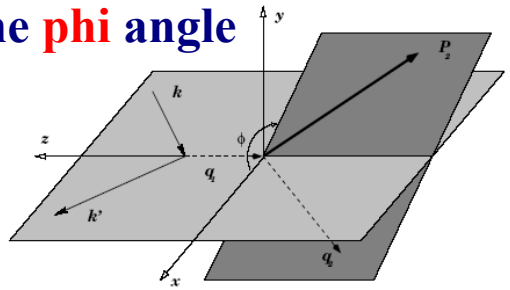
Beam charge-helicity asymmetry: ~ interacion term

|t|-slope: $e^{-b|t|} \Rightarrow \sigma_{DVCS} = |A_{DVCS}|^2 / 16\pi b$

The ratio between the real and imaginary parts of the DVCS amplitude can be extracted:

$$\rho = \frac{\mathrm{Re}\, A_{DVCS}}{\mathrm{Im}\, A_{DVCS}}$$

The phi angle



At EIC:

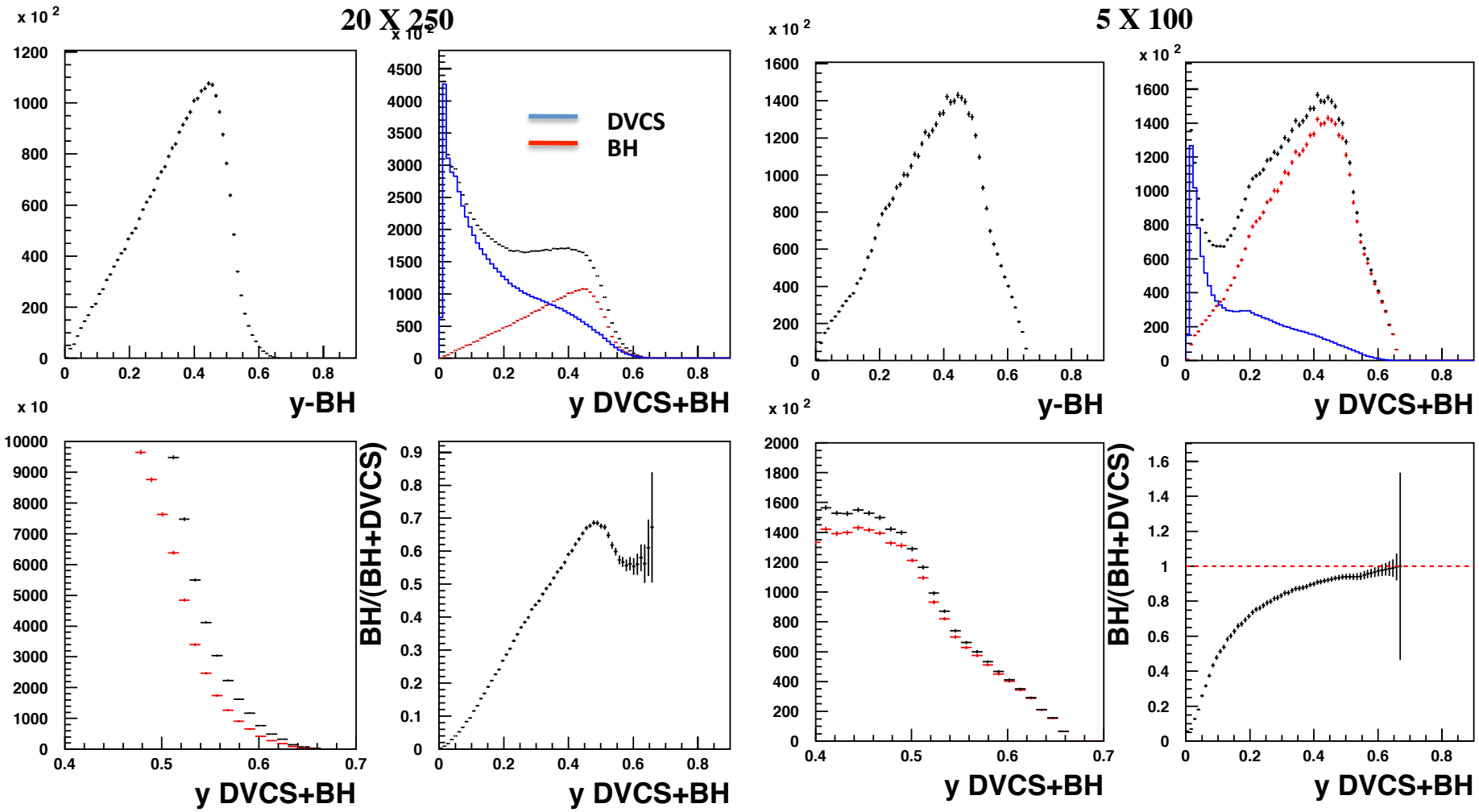
Possible with a positron beam, thanks to a good tracker coverage

- A "cut" on a minimum value (not on its sign!) the angular difference btw the two clusters can affect the phi distribution!
- but we cannot go below the resolution of our em cal!

Crucial!

Our em cal must distinguish two clusters within the order of 1 deg

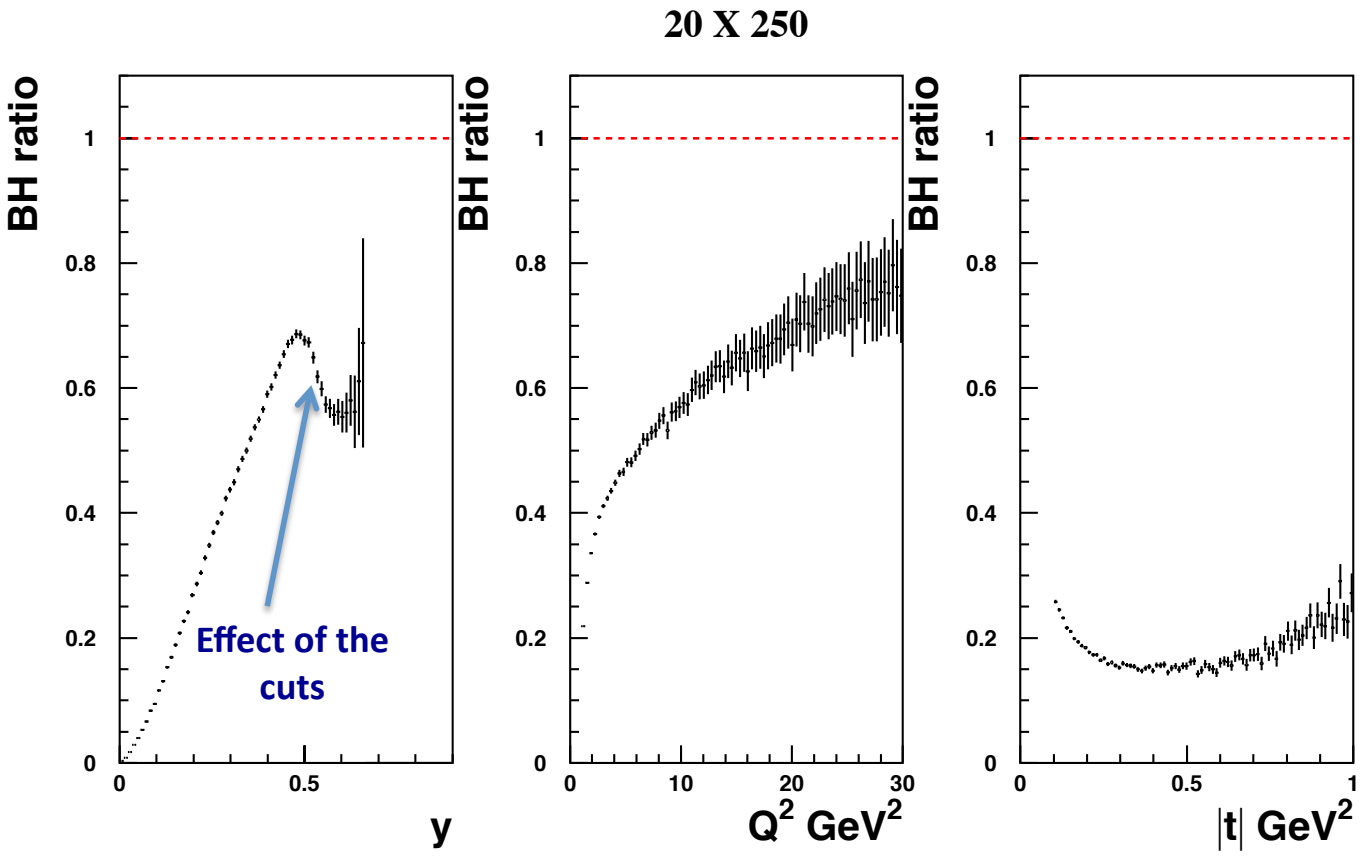
More studies on-going…



Additional selection criteria to reduce BH contamination:

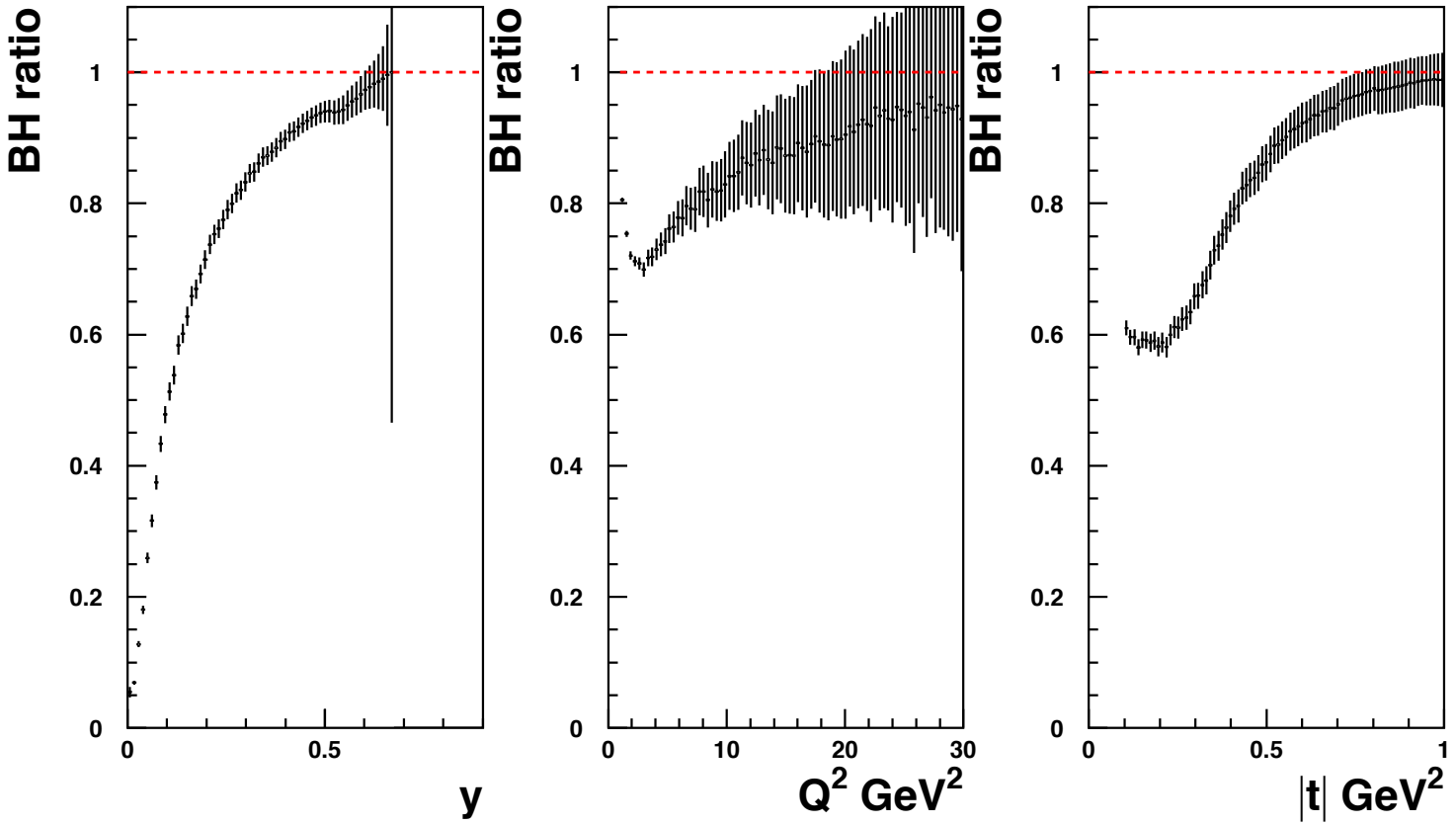
- em clusters to be < 0.02 rad from the beam-pipe (1 deg is the angular acceptance + some “box cut”)
- (th_el-th_g) > 0

DVCS and BH samples normalized at Lumi

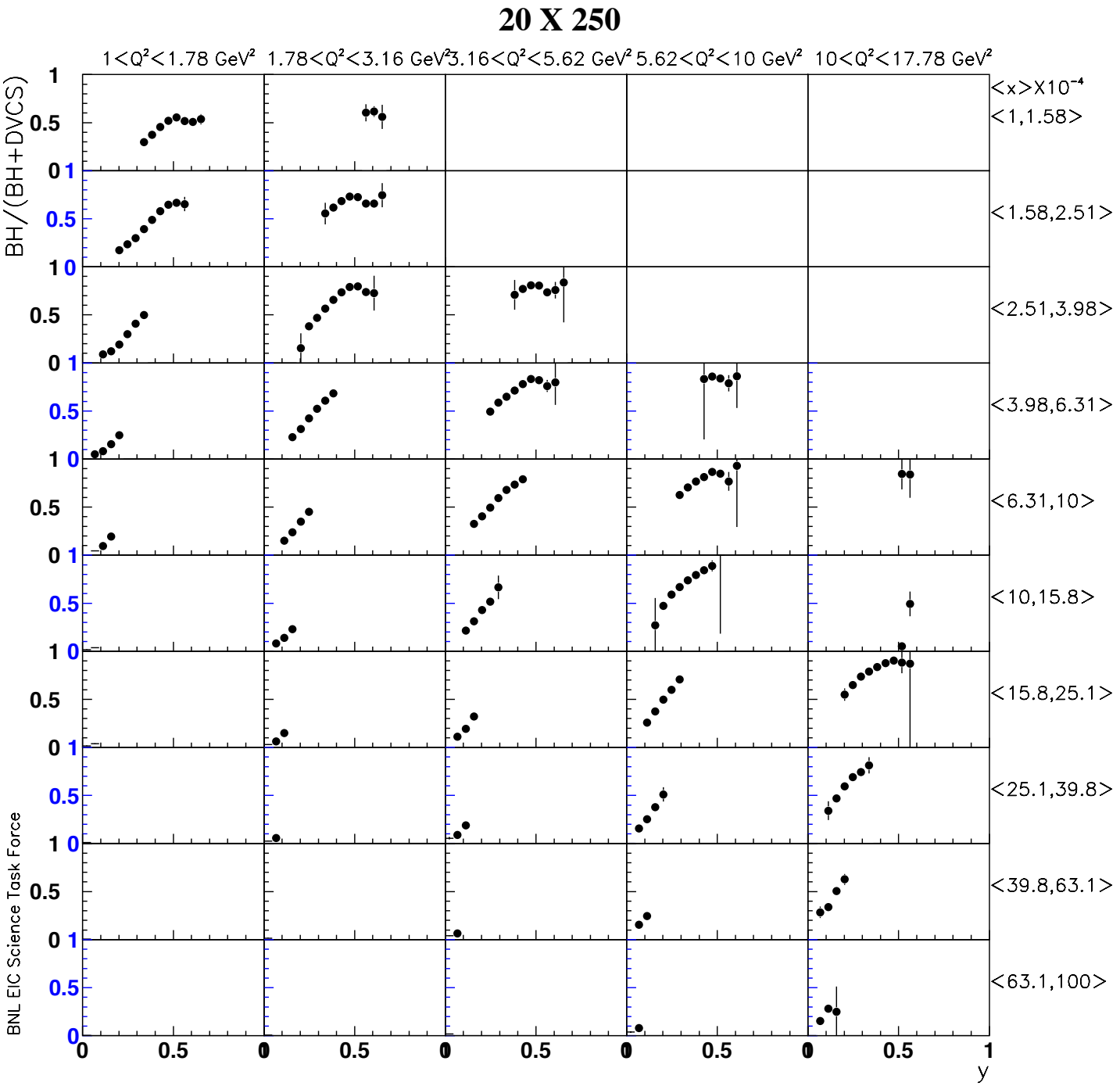


The effect of the cut for the 20x250 conf. is that BH never exceeds 70% of the sample

5 X 100



for the 5x100 conf. is that BH can be a problem at large y and large t, depending on the bin


20 X 250
1<Q²<1.78 GeV²
1.78<Q²<3.16 GeV²
3.16<Q²<5.62 GeV²
5.62<Q²<10 GeV²
10<Q²<17.78 GeV²
<x>X10⁻⁴
<1,1.58>
<1.58,2.51>
<2.51,3.98>
<3.98,6.31>
<6.31,10>
<10,15.8>
<15.8,25.1>
<25.1,39.8>
<39.8,63.1>
<63.1,100>
BH/(BH+DVCS)
y
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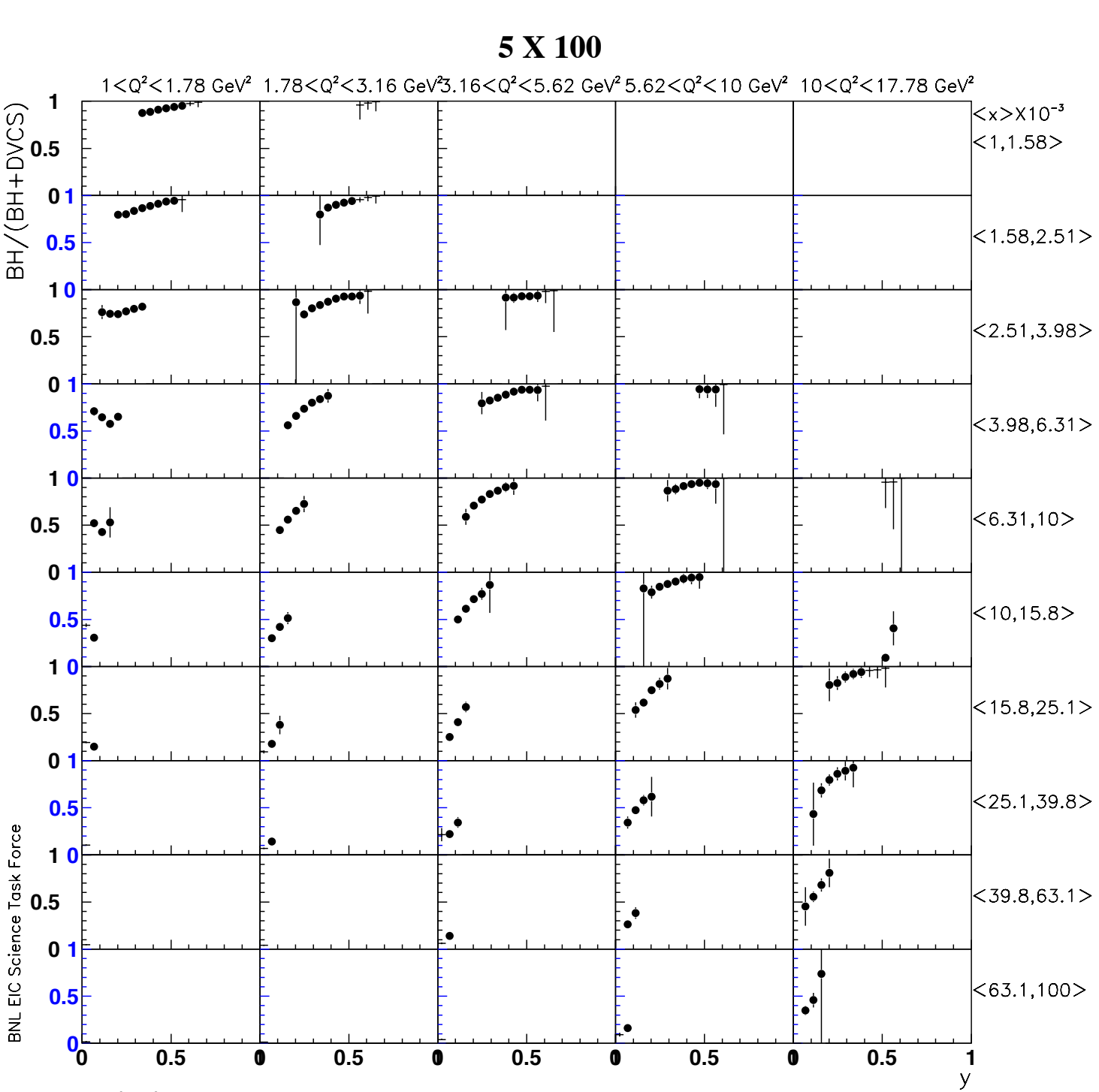
5 X 100
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<x>X10⁻³
<1,1.58>
<1.58,2.51>
<2.51,3.98>
<3.98,6.31>
<6.31,10>
<10,15.8>
<15.8,25.1>
<25.1,39.8>
<39.8,63.1>
<63.1,100>
BH/(BH+DVCS)
y
BNL EIC Science Task Force

Summary

- **We can have a successful program for measuring DVCS differential cross sections in multiple bins of Q2,x,t and in a wider phase-space then ever studied before!**
- **20x250 -> BH can be easily taken under control with an appropriate selection**
- **5x100 -> BH rejection must be studied carefully in order to make reliable simulations of a diff. x-sec. measurement. The limit in y and t will be bin dependent.**
- **We need an e.m. Cal. which:**
  1. **Can discriminate two clusters with angular difference of the order of a degree**
  2. **Can measure clusters down to the energy of possibly 900 MeV**
  3. **Must have a high energy resolution (photon momentum reconstruction)**

Outlook:

- **Simulation mostly over, but to complete:**
  - **20x250 xsec (up to ~100 fb^{-1} also for low t bins)**
- **Study in details the requirements for the detector (em Cal etc…), a mock analysis can be a good hardware driver**

Back up

MILOU

Written by E. Perez, L Schoeffel, L. Favart [arXiv:hep-ph/0411389v1]

The code MILOU is Based on a GPDs convolution model by:
A. Freund and M. McDermott [All ref.s in: http://durpdg.dur.ac.uk/hepdata/dvcs.html]

✓GPDs, evolved at NLO by an indipendent code which provides tables of CFF
- at LO, the CFFs are just a convolution of GPDs:

$$\mathscr{H}(\xi,Q^2,t)=\sum_{u,d,s}\int_{-1}^{1}\left[\frac{e_i^2}{1-x/\xi-i\varepsilon}\pm\{\xi\to-\xi\}\right]H_i(x,\xi,Q^2,t)dx$$

✓provide the real and imaginary parts of Compton form factors (CFFs), used to calculate cross sections for DVCS and DVCS-BH interference.

$$\frac{d\sigma}{dxdyd|t|d\phi d\varphi}=\frac{\alpha^3 x_B y}{16\pi^2 Q^2\sqrt{1+\varepsilon^2}}\left|\frac{\mathcal{I}}{e^3}\right|$$

$$\phi=\phi_N-\phi_l$$

$$\varphi=\Phi_T-\phi_N$$

$$\varepsilon\equiv 2x\frac{m_N}{Q}$$

$$\left|\mathcal{I}_{\mathcal{BH}}\right|^2=\frac{e^6}{x^2y^2(1+\varepsilon^2)^2\Delta^2\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left\{c_0^{BH}+\sum_{n=1}^{2}c_n^{BH}\cos(n\phi)+s_1^{BH}\sin(\phi)\right\}$$

$$\left|\mathcal{I}_{\mathcal{DVCS}}\right|^2=\frac{e^6}{y^2Q^2}\left\{c_0^{DVCS}+\sum_{n=1}^{2}\left[c_n^{DVCS}\cos(n\phi)+s_n^{DVCS}\sin(n\phi)\right]\right\}$$

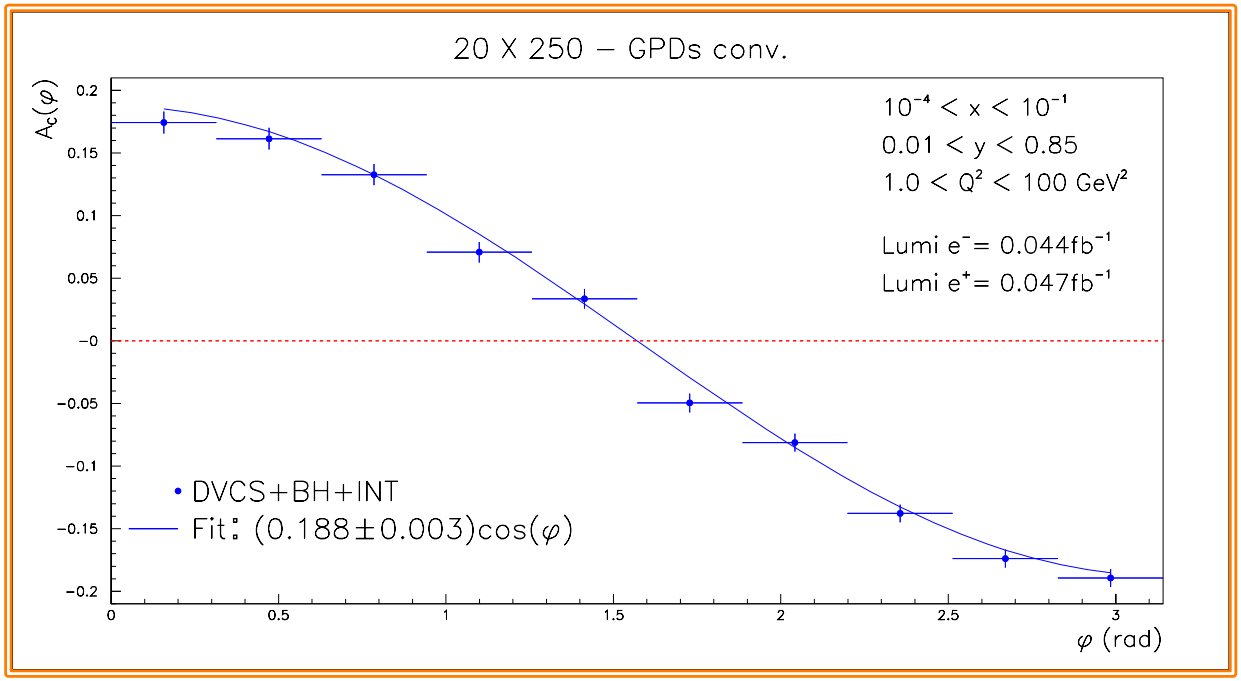
$$|\mathcal{I}|^2=\frac{\pm e^6}{xy^3\Delta^2\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left\{c_0^{\mathcal{I}}+\sum_{n=1}^{3}c_n^{\mathcal{I}}\cos(n\phi)+s_1^{\mathcal{I}}\sin(\phi)\right\}$$

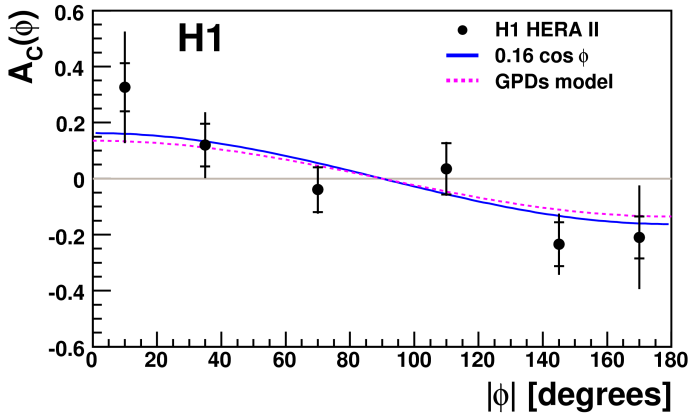
✓ $\frac{d\sigma}{d|t|}=\exp\left(B(Q^2)t\right)$ -> The B slope is allowed to be costant or to vary with Q^2:

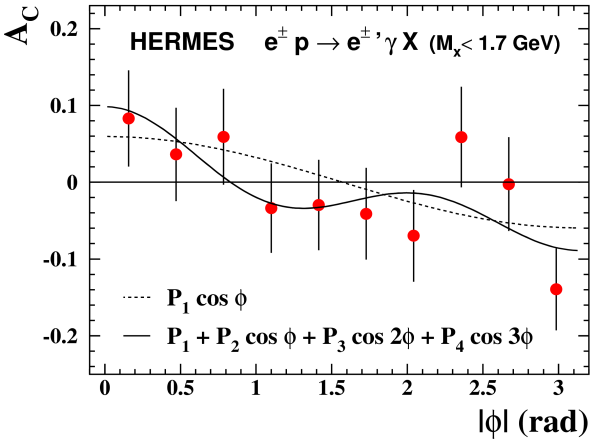
✓Proton dissociation ($ep\to e\gamma Y$) can be included

✓Other non-GPD based models are implemented like FFS, DD

Beam Charge Asymmetry



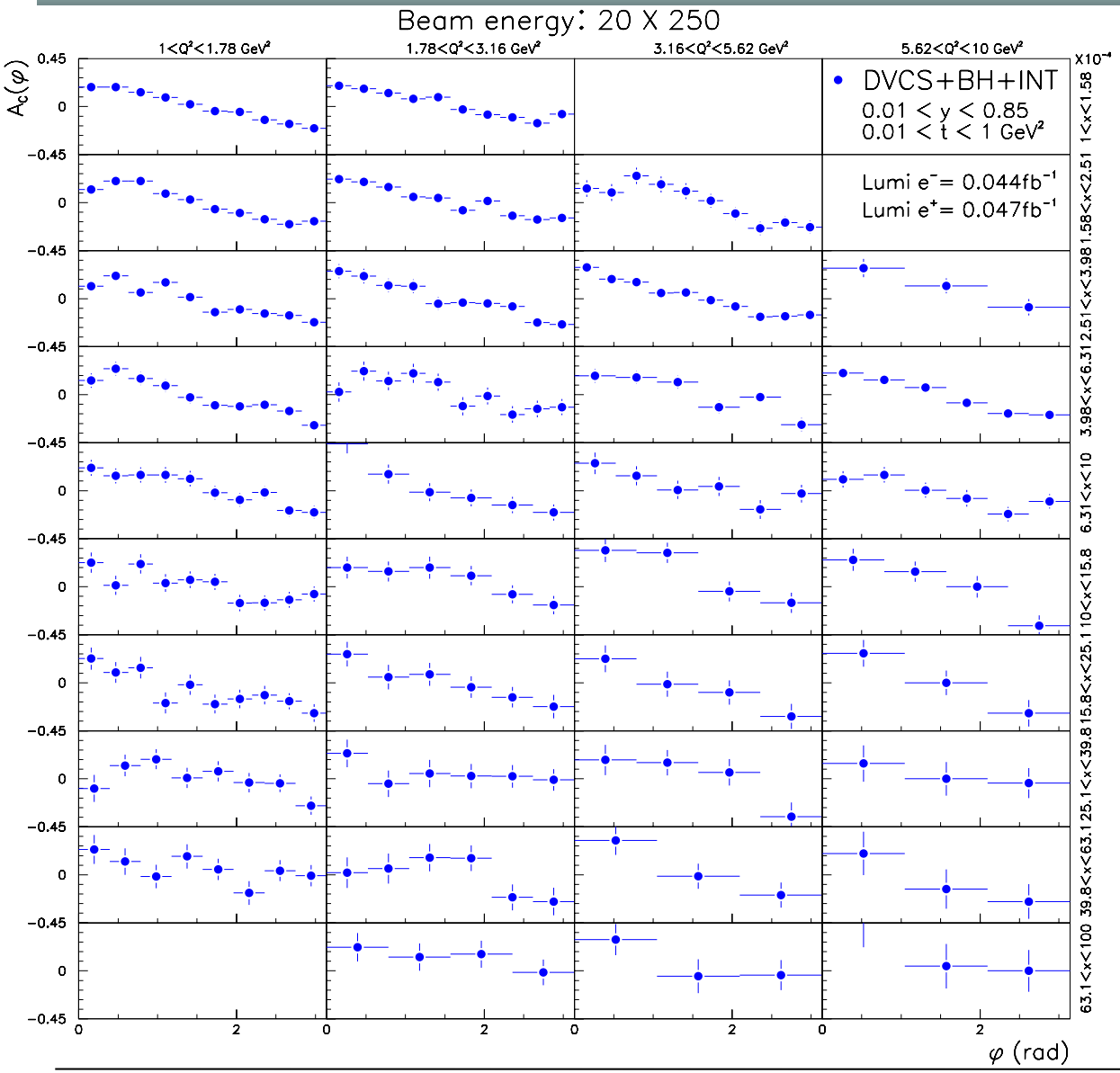




$$A_C = \frac{\frac{d\sigma^+}{d|\phi|} - \frac{d\sigma^-}{d|\phi|}}{\frac{d\sigma^+}{d|\phi|} + \frac{d\sigma^-}{d|\phi|}} = p_1 \cos(\phi) = 2A_{BH} \frac{\mathrm{Re}\, A_{DVCS}}{|A_{DVCS}|^2 + |A_{BH}|^2} \cos(\phi)$$

Excellent measurement with a modest beam-time. Accurate measurements in bins of Q^2 and x are possible! (Simulating more samples…)

Beam Charge Asymmetry



$10^{-4}<x<1.58\times10^{-4}$

$1.58\times10^{-4}<x<2.51\times10^{-4}$

$2.51\times10^{-4}<x<3.98\times10^{-4}$

$3.98\times10^{-4}<x<6.31\times10^{-4}$

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$3.98\times10^{-3}<x<6.31\times10^{-3}$

$6.31\times10^{-3}<x<10^{-2}$

DVCS: the beam-charge asymmetry

$$|A|^2 = |A_{DVCS}|^2 + |A_{BH}|^2 + |A_I|^2$$

DVCS and BH: identical final state → they Interfere

Interference term: $A_I \propto Re(A_{DVCS}) + Im(A_{DVCS})$

$|A_{BH}|$ is well known

Beam charge asymmetry:

$$A_C = \frac{\frac{d\sigma^+}{d|\phi|} - \frac{d\sigma^-}{d|\phi|}}{\frac{d\sigma^+}{d|\phi|} + \frac{d\sigma^-}{d|\phi|}} = p_1 \cos(\phi) = 2A_{BH} \frac{\mathrm{Re}\, A_{DVCS}}{|A_{DVCS}|^2 + |A_{BH}|^2} \cos(\phi)$$

Beam charge-helicity asymmetry: ~ interacion term

|t|-slope: $e^{-b|t|} \Rightarrow \sigma_{DVCS} = |A_{DVCS}|^2 / 16\pi b$

The ratio between the real and imaginary parts of the DVCS amplitude can be extracted:

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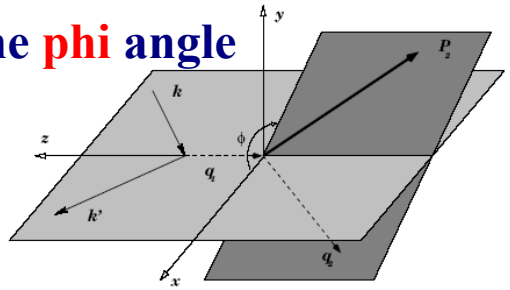
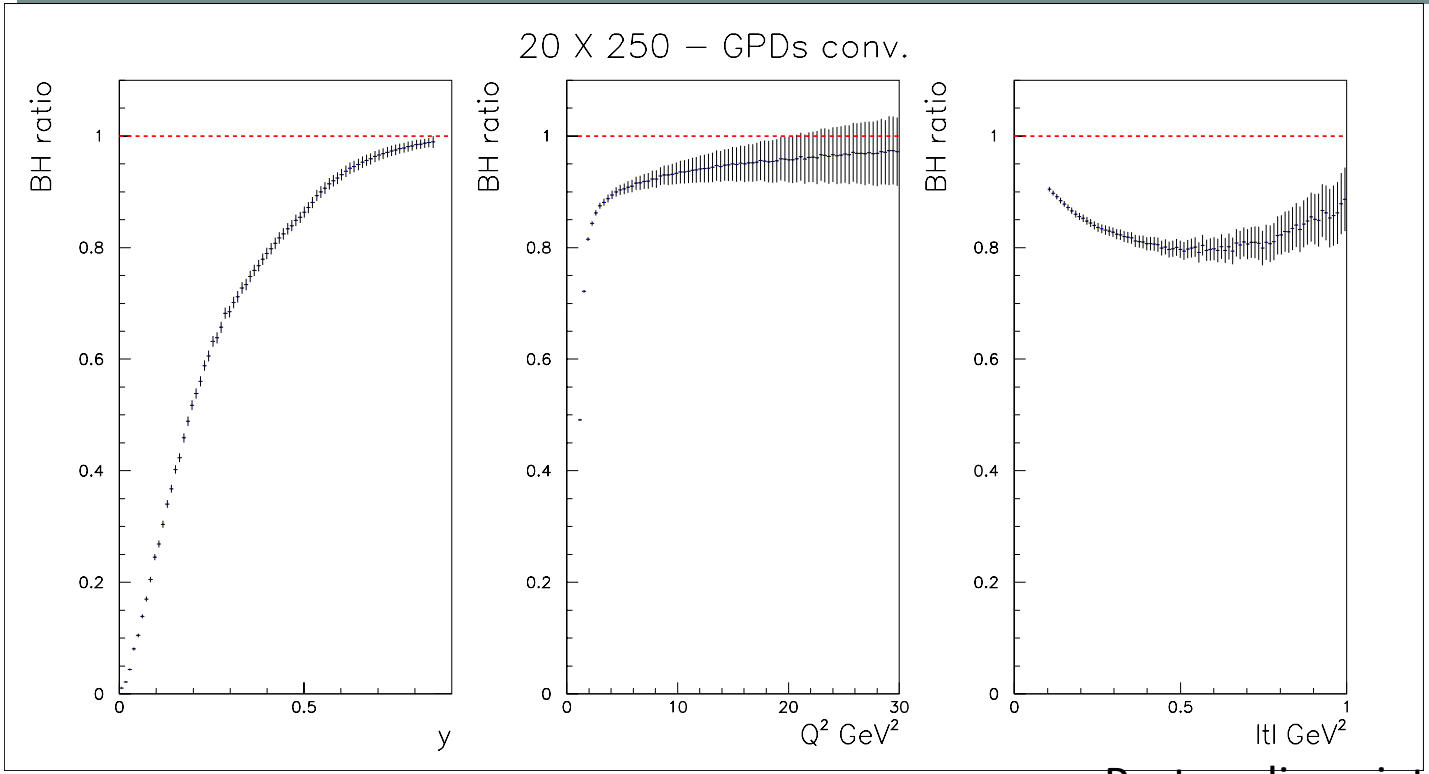
The phi angle



At EIC:

Possible with a positron beam, thanks to a good tracker coverage

Fraction of Bethe-Heitler



$1.0 < Q^2 < 100$ GeV²
$0.01 < y < 0.85$
$0.1 < |t| < 1.0$ GeV²

DVCS and BH samples normalized at Lumi

$$frac(BH) = \frac{BH_{evt}}{BH_{evt} + DVCS_{evt}}$$

BH generated sample much smaller than DVCS one -> error bars

- Proton dissociation not included for both DVCS and BH (but mostly process independent…)
- BH dominates at large y (as expected!)
- Part of BH will be removed by DVCS selection criteria for a DVCS enhanced sample (interference term not affected)

Few thoughts on the systematics

To understand the systematic before having a full detector simulation and even knowing sub-detector specifications it is simply not realistic.

Nevertheless, to have a quantitative idea of the order one can expect, I looked at the ZEUS DVCS-analysis (using Roman Pots). Here are their main sources of systematics:

- Beam-halo, (E+Pz+2Pz(RP)<1860 GeV → only 3% bkd survives (negligible @ ZEUS)
- t resolution → bin properly, accordingly to resolution.
- X coordinate in RP → this syst. Was due to an inaccurate simulation of the RP detectors.
- Minimum approach of the track to the beam-pipe

TOTAL = 8%

- LUMI (2.25%) → does not affect the t-slope

$\pi^0 \rightarrow \gamma\gamma$ was found negligible (@ HERA but @ eRHIC?)

For the moment, for the purpose of fits using pseudo-data, we'll be using a realistic value of 5%